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Supervisory Channel in an Optical Network System

The present invention belongs to the field of optical communication systems and, more particularly, to dense wavelength division multiplexed optical networks with arbitrary topology, e.g., point-to-point, ring, mesh, etc..

The soaring demand for virtual private networks, storage area networking, and other new high speed services are driving bandwidth requirements that test the limits of today's optical communications systems. In an optical network, a node is physically linked to another using one or more optical fibres (cf. Fig. 1). Each of the fibres can carry as many as one hundred or more communication channels, i.e., wavelengths in WDM (Wavelength Division Multiplex) or Dense WDM (DWDM) systems. Thus, for example, for a node with three neighbours as many as three hundred or more wavelength signals originate or terminate or pass through a given node. Each of the wavelengths may carry signals with data rates up to 10 Gbit/s or even higher. Thus each fibre is carrying several terabits of information. This is a tremendous amount of bandwidth and information that must be managed automatically, reliably, rapidly, and efficiently. It is evident that large amount of bandwidth needs to be provisioned. Fast and automatic provisioning enables network bandwidth to be managed on demand in a flexible, dynamic, and efficient manner. Another very important feature of such DWDM networks is reliability or survivability in presence of a failure such as an inadvertent fibre-cut, various types of hardware and software faults, etc. In such networks, in case of a failure, the user data is automatically rerouted to its destination via an alternate or restoration path. For example, for the mesh network shown in Fig. 1, the primary and restoration paths are as follows:

Demand ID	End Nodes	Protocol	Primary Path	Restoration Path
D1	[#1,#5]	A	#1 <-> #2 <-> #5	#1 <-> #4 <-> #5
D2	[#1,#3]	C	#1 <-> #2 <-> #3	#1 <-> #4 <-> #3

Table 1

Note that if the primary paths of demands D1 or D2 fail due to the failure of link #2-#5 or link #2-#3, a single wavelength channel over link #1-#4 could be used to restore both demand-ids D1 and D2. This is due to the fact that under single point of failure assumption, either link #2-#5 or link #2-#3 fails but not both at the same time. Thus as opposed to 1+1 where a 100% overcapacity is required for survivability, the same extra capacity can be shared between different demands for restoration. This results in significant savings in overall extra capacity required to realize survivable DWDM systems.

There have been proposals to create such mesh networks using cross-connects, which in case of core networks with several neighbours and large wavelength count, require gigantic switch matrices or cross-connects and several O/E and E/O conversions making the cost of such a system prohibitively expensive. While a handful of the national and international carriers are able to afford such expensive systems, such systems are outside the budget of small and local carriers and enterprises, which operate the so-called metro, or enterprise networks. Such networks require relatively smaller number of wavelengths but tend to be more „meshy“ than core networks. Thus it follows that there is a tremendous need for DWDM systems, which are highly modular and low-cost and which can be scaled both upwards and downwards in capacity and cost for smaller customers. The situation is analogous to the case of the personal computer and mainframes, where the customer wants and needs some of the key features of a complex and large system but needs and can afford to pay for only a small (in terms of hardware) system. Automatic provisioning and restoration is highly desirable but at present is unaffordable for metro or enterprise networks. In such a network a complete protection/restoration of the network under single point of failure is provided.

Up to now, to increase capacity, carriers implement protocol dependent architectures and switches/cross-connects, e.g. SONET(Synchronous Optical

Network)/SDH (Synchronous Digital Hierarchy) multiplexing with its ring architecture, ATM (Asynchronous Transfer Mode) and fibre-channel switches, etc. Such networks, which provide protection against multiple types of failures including the fibre cut, are expensive and work only for ring architecture and specific protocols.

It is an object of the present invention to overcome the disadvantages of the state of the art and especially to provide a network element for use in an optical network to create intelligent, transparent, any-protocol-at-any-time, high speed systems comprising multiple nodes in an arbitrary topology, e.g., point to point, ring, mesh, etc. Moreover, an optical network with a network management system built up from such network elements should be provided. In particular, a supervisory network should be provided for information exchange between various nodes in an optical network with arbitrary topology.

The object of the invention is realized by an optical network element according to claim 1, a corresponding optical network according to claim 7 and a method of providing a supervisory network in an optical network according to claim 11. The subclaims describe preferred embodiments of the invention.

With one or more of the network elements according to the invention an intelligent optical network could be build up or an existing network could be adapted or scaled up to an intelligent system. Intelligence refers to, among other things, how information related to various aspects of network configuration, operation, and management is stored in the network. Information refers to any details related to the state of network elements, the state of the network, various primary and redundant paths through the network, configuration data, and any other data which is pertinent to the optical network management system, etc.. All information can be a) stored at a single node, b) duplicated over several or all network nodes, or c) distributed over several or all network nodes. The distributed approach c) scales well as the number of nodes increases because any single node needs to deal

with a reduced amount of information. But a software overhead penalty must be paid because the various pieces of information must be obtained from various nodes and inconsistencies between any duplicated information must be resolved. An alternative is to store all the information at a single node (approach a), which can be accessed by any user at any of the network nodes, or a user located elsewhere such as one or more management offices. However, if this node fails all the valuable data is lost. In order to solve this problem, the same data can be stored at several or all network nodes (approach b). In case one of the network nodes fails, the data can then be retrieved from one of the several other nodes which carry a copy of the original data. Another aspect of intelligence involves who takes the required management actions and how. A management action involves performing a set of tasks and can be carried out in a centralized, distributed, or hybrid manner. The various tasks can in turn also be performed in a centralized or distributed manner. In the centralized approach a single task is carried out for example by one or more software agents residing at various nodes. A software agent is a software process or an execution thread which is used to implement a certain software functionality.

The optical network element according to the present invention for use in a node of an optical network including a plurality of nodes which are interconnected so as to be capable of carrying traffic between selected nodes comprises a local network management system. The local network management system includes means for building up a supervisory connection between the respective network element and at least a further network element of a further node of the optical network. The local network management system, that means the network management system of a specific network element in the network, is able to support an arbitrary network topology so as to build up a supervisory connection to at least one other node of the network with the arbitrary topology. Therefore, the optical network element according to the present invention could be integrated in an optical network with arbitrary topology, for example either in an existing network or a new network comprised of a plurality of network elements according to the invention.

In a preferred embodiment the network element is provided with a local network management system that provides self healing of the supervisory connection between the respective network element and a predetermined further network element of the network. Thereby, self healing means, that in the event of an impairment of a specific supervisory connection the local network management system re-establishes the respective supervisory connection or establishes an alternative supervisory connection between these nodes which were interconnected by the now disrupted supervisory connection.

Preferably, the local network management system comprises of a software module which acts as a node manager. This node manager preferably includes one or more software agents, which are described in further detail in the following with reference to the figures.

In a preferred embodiment, the local network management system has the flexibility to be configured by standard software protocols, for example by OSPF (Open Shortest Path First) which is a routing protocol used in general within larger autonomous system networks in preference to the RIP (Routing Information Protocol). However, of course the network management system according to the present invention could be configured by RIP. A further protocol by which the local network management system could be preferably configured is the MPLS (Multiprotocol Label Switching). Multiprotocol Label Switching is a versatile solution to address the problems faced by present-day networks, for example speed, scalability, quality-of-service management, and traffic engineering.

In a preferable embodiment the local network management system is provided with a functionality that provides an automatic discovery of network elements of adjacent network nodes and an automatic exchange of Link State Advertisement with the discovered network element.

A very preferable embodiment of the network element according to the invention is an intelligent network element which comprises of at least one back-plane with a plurality of electrical transmission lines, which run across the back-plane. Furthermore, the back-plane contains a plurality of electrical terminals, which are connected to the transmission lines for attaching of electrical devices such as various cards and/or circuit packs with determined circuitry that should be interconnected by the back-plane.

The hardware structure of the network element according to these very preferable embodiment is described in the application 02007008.2 from the same applicant, filed with the EPO on 27.03.2002, the disclosure of which is incorporated into the present application by reference. As described, these network element further comprises at least one of a first line-card slice with at least one receiver for receiving of optical signals from a predetermined path of the optical network in which the network element is integrated. The network element furthermore comprises of at least one of a second line-card slice with at least one transmitter for transmitting of optical signals to a predetermined path of the optical network. The line-card slices can be local line-card slices or remote line-card slices, for example the said first line-card slice could be a local line-card slice and the said second line-card slice could be a remote line-card slice. However, it is also possible to provide to local or remote line-card slices, one for receiving and one for transmitting of optical signals from respective to the optical network, or both for receiving and transmitting of optical signals. The terms „local" and „remote" are used herein to distinguish between two line-card slices, which provide transmit/receive interfaces to local user equipment in a central office or data centre and the user equipment located at a remote node.

Each line-card slice with a receiver comprises an opto-electrical converter for converting the received optical signals to electrical signals. The opto-electrical converter could be integrated in the receiver (so-called opto-electrical receiver) or attached as an independent device to the receiver. The at least one electrical

terminal of the opto-electrical converter is attached to one or more electrical terminals of the at least one of the electrical terminals of the line-card slice.

Each line-card slice, which comprises a transmitter, is provided with an electro-optical converter, which could be integrated in the transmitter (so-called electro-optical transmitter) or attached as an independent device to the transmitter. The electrical terminal of the electro-optical converter is connected to one or more of the at least one of the electrical terminals of the line-card slice.

The line-card slices are plugged – directly or indirectly, with the latter preferably by means of a chassis – into the back-plane such that the electrical terminals of the line-card slices are connected to the electrical terminals of the back-plane and thereby the electrical terminals of various line-card slices are interconnected, thus allowing them to communicate with each other, via the electrical transmission lines in the back-plane.

The network element according to the preferable embodiment comprises a plurality of switch terminals, which are provided between the converters of various line-card slices and/or between various converters on a single line-card slice. The switch terminals allow providing predetermined but reconfigurable electrical interconnections between various optical receivers and transmitters in the network element. The switch terminals may be provided on the back-plane, however, it is preferred to provide them on the line-card slices such that one or more of the electrical terminals of a converter on a line-card slice could be electrically connected to a predetermined electrical terminal or set of terminals of the line-card slice or to one or more of the electrical terminals of one or more further converters on the same line-card slice. Preferably, the switch terminals allow reconfigurable interconnections among various electrical terminals by using software or software commands, this means intelligence offered by software can be used to determine in real-time as to which terminals are interconnected in order to react dynamically to the various possible network states. To provide the reconfigurable electrical

interconnections are preferably used electrical switches or – as described in the following – electrical cross-connects.

For switching of signals from a first path to a second path – for example primary path to restoration path – the network element preferably comprises at least one electrical cross-connect having first electrical terminals for receiving and/or input of electrical signals and second electrical terminals for transmitting and/or output of electrical signals. The electrical cross-connect directs electrical signals from selected first to selected second electrical terminals, thereby determining the way of the signals through the network. The electrical cross-connect is plugged into the back-plane – directly or indirectly – whereby the electrical terminals of the cross-connect are connected to the electrical terminals of the back-plane so that the first electrical terminals are interconnected via the electrical transmission lines of the back-plane to electrical terminals of selected first line-card slices (with at least one receiver) and the second electrical terminals of the cross-connect are interconnected via the electrical transmission lines to electrical terminals of selected second line-card slices (with at least one transmitter).

To keep the electrical connections between the line-card slices and the cross-connect short in order to achieve low signal attenuation the line-card slices and the at least one cross-connect are preferably distributed on the back-plane in such a way that each cross-connect is electrically sandwiched between a predetermined number of line-card slices with at least one receiver and line-card slices with at least one transmitter. By this arrangement the electrical signals from a first line-card slice, e.g. a local line-card slice, are transmitted over very short transmission lines to the cross connect and then further from the cross-connect over very short transmission lines to the second line-card slice, e.g. a remote line-card slice. The various line-card slices and electrical cross-connects can be attached to the back-plane for example either directly or as plug in modules.

Especially in bi-directional network architectures each line-card slice comprises preferably both of one optical transmitter and one optical receiver together with the corresponding converters. In bi-directional network architectures each node is connected to another node by at least two separate lines for signal traffic with signals travelling in opposite directions. The signals reaching one node are received and converted by the receiver and the signals leaving the node are preferably converted and transmitted by the optical transmitter of each line-card slice, respectively.

For use of the network element in a DWDM network system the network element comprises preferably at least one filter-unit for transforming of the optical multi-wavelength signals into individual wavelength channel signals. The filter-unit is arranged in an optical path before (with respect to the flow of optical signals) an optical receiver of a line-card slice or behind an optical transmitter of a line-card slice. The filter-unit is preferably implemented in one or more filter-cards, which are pluggable – directly, or indirectly, the latter preferably by means of a chassis – into the back-plane. By use of the transmission lines running across the back-plane and the corresponding electrical terminals the filter-units or cards could be electrically managed and controlled via the back-plane or by means of electrical devices attached to the back-plane.

The filter-unit advantageously comprises a modular structure with various stages, whereby each stage comprises of at least one of a band-pass filter, an interleaver and a DWDM filter. By using a modular structure a very high flexibility and low costs for producing and integrating of the filter-units in the network element could be reached.

For providing of very high data rates the network element comprises preferably a single back-plane for providing of the electrical connections between the different devices such as line-card slices, electrical cross-connects, filter cards etc. Furthermore, by combining of DWDM line-card slices, filters, and optical cross-

connect functionality in a single hardware unit of the network element, highly flexible and reliable optical network architectures can be realized that can support arbitrary data protocols. The hardware in such networks combined with sophisticated software intelligence can be used to support advanced features such as dynamic provisioning/bandwidth trading, remote performance monitoring, and fast automatic restoration, etc. Intelligent optical switches and cross-connects can be used to support virtually any network topology including point-to-point, ring, and mesh architectures, allowing service providers, to evolve their existing infrastructures while immediately cutting both capital and operating costs. Whereas survivable ring architectures mandate the reservation of 100% excess capacity, mesh architectures leave the choice of protection to the service providers themselves, reducing costs by as much as 70% with acceptable critical restoration times. The present invention allows the operator to achieve varying levels of flexibility and survivability in optical networks and trade off costs with desired features and vice versa.

The network element according to the preferable embodiment of the present invention supports one or more uni-directional optical fibre links between a pair of nodes without any restriction to the total number of the nodes in the network or to the number of nearest neighbours which a given node can have. Each uni-directional or bi-directional optical fibre links supports multi-wavelength signals. In one preferred embodiment the maximum number of wavelengths in the aforementioned multi-wavelength signals is seventy two.

The components of a given network element according to the preferable embodiment of the invention are bit-rate and protocol transparent. This implies that the network element is configurable to various bit-rates and data networking protocols under the intelligence provided by hardware and software programming under static or dynamic/real-time operation conditions. The network element could be used to built optical networks with arbitrary topology to provide automatic or point-and-click provisioning, fault protection/restoration, and other services such

as band-width trading, etc. with a centralized distributed, or hybrid form of network management system, which comprises various software modules as described later in this document.

The network element of the above described preferable embodiment further comprises of a supervisory card plugged to the back-plane for transmitting and/or processing of supervisory signals. The supervisory card is preferably electrically connected via the electrical transmission lines of the back-plane to a predetermined line card slice directly or through a cross-connect.

Further, the network element could contain a node PC, especially also in form of a plug-in card, plugged to the back-plane. The node PC provides an electrical supervisory signal that is transmitted to the supervisory card.

Furthermore, the present invention provides an optical network comprising a plurality of network elements according to the invention. The network management system of the optical network according to the invention, which could be called global network management system in contrast to the local network management systems of the single nodes, is carried out by one or more of the local management systems of the network elements. The optical network according to the present invention consists of among other things supervisory connections between predetermined network elements.

In a preferred embodiment the network management system provides the establishment of a direct logical supervisory connection between any desired pair of nodes interconnected by one or several physical supervisory connections. This means, although two specific nodes are connected by a sequence of several physical supervisory connections, for example via several nodes of the network, to provide one or several end-to-end supervisory connections so that the said pair of nodes can exchange information between each other. The logical supervisory

connection allows a unidirectional and/or bi-directional communication channel as needed.

The network management system of the optical network according to the invention preferably provides one or several of the following functions, comprising of hardware fault detection and/or software error detection especially on all of the supervisory connections: auto-recovery from various faults and errors, that is, self-healing of supervisory connections, fault tolerant and/or redundant supervisory connections, and automatic discovery of nodes of the network.

A method according to the invention allows an intelligent management of an optical network by providing a supervisory network in an optical network with arbitrary topology. The method according to the invention comprises of the steps of automatic discovery of the network topology and establishing of supervisory connections between predetermined nodes of the network.

The automatic discovery of the network topology is preferably done by one or more node managers of a local network management system in a network element of a node by communicating with the local network management system of an adjacent node and exchanging Link State Advertisements. Each node, namely, the node manager of each network element in each node discovers all of its adjacent nodes and exchanges Link State Advertisements with the same. Thereby a routing table is generated that could be stored in one, several or in all of the nodes of the network.

Preferably, the node manager of each node executes a single OSPF, whereby the OSPF in each node is configured to communicate with the node manager of adjacent nodes so that the OSPF converges on the topology of the network, that means on the whole network.

The status of the supervisory connections is preferably monitored, preferably by OSPF, and in the event of a link failure an alternative route for the respective supervisory connection is configured.

In one embodiment of the invention any supervisory data for use in the supervisory management layer of the network, which in turn is carried by the optical network, is sent through one or several or possibly all available redundant connections in form of messages. Thereby, the supervisory data corresponding to the messages is/are sent from one sending end of the network to one receiving end of the network. Each message is given a sequence number. On the receiving end the duplicate messages are discarded and only one of the several, for example arriving messages is passed on to the supervisory management layer.

In the following, preferred embodiments of the invention should be described in more detail with reference to the figures.

Figure 1 shows examples of network topologies in which the present invention could be used;

Figure 2 shows software architecture for building up a supervisory channel;

Figure 3 shows examples of software agents contained in a node manager;

Figure 4 shows examples for an implementation of a supervisory channel;

Figure 5 shows the implementation of a supervisory channel in a network by means of a plurality of physical supervisory channel connections;

Referring to Figure 2, 'n' local network management systems 11 of 'n' optical network elements in a network of arbitrary topology are shown. The network elements with their local network management systems 11 are interconnected by

means of supervisory connections 10.1. The several supervisory connections 10.1 define together a supervisory channel 10, which preferably interconnects all of the nodes of the network by a respective plurality of supervisory connections.

The local network management systems 11 comprise a software module, a so-called node manager 100. Every shown node manager 100 can be configured by a software protocol 110 and uses the shown software modules 110, called NetProc to communicate with the node manager of a further network element.

With reference to Figure 3, software architecture for a node manager is shown, which could preferably be implemented in a network element in one embodiment of the present invention. Note that this node manager in addition to the local hardware management serves as a centralized network manager and/or as one of the several distributed network managers for the entire optical network. In particular, it unifies point-to-point, ring, and mesh architectures and is also scalable, affordable, robust, and reliable. Some of the examples of software agents as shown in the Figure 3 are start-up manager 101, process, thread, and sessions manager 102, supervisory channel process manager 103, hardware devices manager 104, status, fault, and events manager 105, database system manager 106, user interfaces (e.g., GUI, console, TL1, etc.) 107, System Resources and Functions Manager 108.

In the distributed management approach a single task is carried out by one or more software agents residing at various nodes. A management action is said to be carried out in a centralized mode if all of the tasks it is comprised of are carried out in a centralized manner. A management action is said to be carried out in a distributed mode if all of the tasks it is comprised of are carried out in a distributed manner. A management action is to be carried out in a hybrid mode if one or more of the tasks it is comprised of are carried out in a centralized manner while others are carried out in a distributed manner. For example, in case of a fault in the optical network the management action may involve the following tasks: 1) fault

detection/isolation, 2) fault signalling to the network management system (which itself may be centralized, distributed, or hybrid), 3) alternate path calculation and allocation, 4) signalling for restoration activation, 5) optical signal switching at various nodes (6) updating various databases and reclaiming the system resources, 7) restoring the failed hardware or software. Each of these tasks can be carried out using a software agent located at a single node or several nodes. Thus this management action can be completed using a centralized, distributed, or hybrid approach.

The management system of an optical network with arbitrary topology, see for example Figure 1, especially the local management system of a network element in a single node utilizes a supervisory channel to provide the necessary intelligence by signalling with other nodes to manage the network and also to resolve any problems which may occur. In general, the realization of supervisory channel requires both, hardware and software support. In a preferred embodiment of the present invention, the software module which implements the supervisory channel is termed NetProc, which enables a supervisory communication link between any two nodes in the supervisory network. In an optical network a network element according to one embodiment of the present invention and a software module called NetProc when combined together provides the following supervisory network features:

1) Supervisory connection establishment between two network nodes. Each node can have one or more NetProcs. This architecture allows establishment of a direct logical supervisory connection between any arbitrary pair of nodes interconnected by the supervisory channel (cf. Fig. 2).

   Fault-tolerant or redundant connections through two or more paths. In a preferred embodiment these paths are node and link disjoint, as will be described in more detail. The management system uses NetProc's services to exchange messages with other nodes. Any supervisory data is sent

through one or several or all of the available redundant connections. Each message is given a sequence number. On the receiving end the duplicate messages are discarded and only one, for example the first, of the arriving message is passed on to the supervisory management layer.

2) Hardware fault and software error detection on all paths of the supervisory channel and the associated auto-recovery to re-establish the supervisory channel. Error checking in the data transmission is done by using sequence numbers on the messages. The status of each connection is monitored by sending keep-alive messages at regular intervals. In the event that a reply to keep-alive message is not received within a specified time the connection is explicitly closed and the two nodes try to re-establish connection between themselves. The closing of connection(s) and attempts to re-establish them are done automatically.

3) Relaying information reliably to one or more network managers running on one or more network nodes or other work stations.

4) The management of the network is carried out by a node manager present in each node or at one or more nodes or other centralized locations. The various node managers communicate using the NetProc (cf. Fig. 2).

A preferred supervisory network according to the invention has the flexibility to be configured by standard protocols like OSPF, MPLS or by using NetProc. Following features apply:

- The supervisory network topology is automatically discovered with the help of OSPF. Each Node Manager executes a single OSPF and the OSPF in each node is configured to talk with neighbouring nodes.
- The nodes discover their neighbours and exchange Link State Advertisements. Once the Link State adjacencies are formed and the OSPF converges on the topology, each node possesses the routing table and is able to reach other nodes over the supervisory channel.
- The status of the supervisory channel is monitored by OSPF and in the event of link failure the alternate routes are configured. Fault-tolerant connections

are set up using two or more Label Switched Paths over two or more disjoint paths to each destination. Thus a signalling message sent to a node travels through multiple Label Switched Paths and reaches its appropriate destination.

With respect to the Figures 4 and 5 the hardware architecture for the supervisory channel in a preferred embodiment of the optical network according to the present invention is shown and furthermore the communication of supervisory messages.

An out-of-band supervisory channel is implemented either by using one of the wavelengths on each fibre link between a pair of nodes or a 1510 nm signal (outside the EDFA amplifier range) is used (cf. Fig. 4a). Alternatively, an in-band supervisory channel can be implemented using electrical (de)multiplexer (cf. Fig. 4b) which can be done using special purpose chips implementing bit or byte processors. As an example, in the special case of SONET/SDH protocol, an in-band supervisory channel could be implemented by (de)multiplexing data from/into the DCC channel. In preferred network systems, the node PC (through an appropriate plug-in card) provides an electrical out-of-band supervisory signal which is connected to the supervisory card (SC). The supervisory signals terminated at SC cards are connected to suitable default remote line card slices using back-plane connections of the chassis. However, in case of fault the supervisory signal can be switched to alternate line-card slices using one or more cross-connects. The supervisory card provides interfaces for multiple supervisory signals from/to various nodes to the node controller PC of the said node.

As shown in Figure 5, the same physical supervisory channel over the link $X \leftrightarrow Y$ using whether in-band or out-of band signalling or any other arrangement could be used to establish a logical supervisory connection using paths S1: $Z1 \leftrightarrow X \leftrightarrow Y \leftrightarrow Z2$ and S2: $U \leftrightarrow Z1 \leftrightarrow X \leftrightarrow Y$, where S1 and S2 are the supervisory channels and the corresponding supervisory connections between nodes (Z1, Z2) and (U, Y), respectively. In order to achieve this the supervisory signals for different logical channels are multiplexed, demultiplexed, and routed through a particular node.

The multiplexing and demultiplexing of supervisory messages is done, e.g., in time domain using either time division multiplexing and/or statistical multiplexing techniques. Thus each node acts like a multiplexer, demultiplexer, router/switch/cross-connect, sender, and receiver for arbitrary number of supervisory messages which may pass-through it or originate/terminate at it. The messages arriving via the supervisory channel at a node are sent to the Node Manager. The Node Manager decides where to route the message and chooses the appropriate outgoing port/interface. The message is then carried over the fiber to the next node as explained above.

A supervisory channel could be preferably used to manage the entire optical network. Thereby, the supervisory channel can be used to manage the network using existing standards such as SNMP or proprietary protocols. The supervisory channel enables preferably a uni-directional or bi-directional logical connection between any pair of nodes over redundant paths. This ensures that the logical communication between any pair of nodes will survive under the single failure assumption involving failure of any single link or a single node except for the two communicating nodes themselves. Let (Z1, Z2) represent a node pair. The logical connection between Z1 and Z2 is established through two or more node-link-disjoint paths, e.g., Z1↔Z2, Z1↔V↔Z2 and Z1↔X↔Y↔Z2, etc.. The number of node-link-disjoint-paths available depends on the actual topology of the optical network. If more than two node-link-disjoint paths are used between the communicating nodes, survivability of the supervisory channel against multiple failures can be achieved. A redundant (additional) supervisory card is preferable provided in every main card chassis, that means for example in every the back-plane receiving chassis of a single network element, to protect against the failure of the first supervisory card.

Reference Numerals

1 .. 9, A .. F, U, V, X, Y, Z	Nodes
10	Supervisory channels
10.1	Supervisory connection
11	Local network management system
100	Node manager
101 .. 108	Software agent
110	Software module